

PROJECTING REGIONAL AREA CHANGES IN FORESTLAND COVER IN THE U.S.A.

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ABSTRACT

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Long-range regional projections of the changes in forest type areas are important in public and private forest resources planning. The combination of natural forces and human activities, which are shaped by socioeconomic forces such as population and income trends, has led to striking changes in forest cover types for the three major types of private owners. A model for the U.S. Southeast is presented that projects future areal cover on each ownership by forest type for several land management scenarios. Planned research includes development of regional type transition models based on forest ecosystem responses to various disturbances with consideration of vital silvical attributes of species groups.

INTRODUCTION

Assessments of forest and range market trends are important for nationally coordinated long-range planning involving publicly owned forest resources as well as for state-level planning. Two key aspects of the forestland base are changes in land use and vegetative cover. Land use shifts involving forestry are important because of export demands for food and fiber products. More than 4.45 million ha of the southeastern United States forestland (15% of the timberland base) have been identified as having high or medium potential for conversion to cropland (Dideriksen et al., 1977).

Our primary concern in this paper is examination of regional vegetation dynamics in forestry. In spite of the fact that a mixture of natural and human disturbances shape forest developmental processes, previous studies of forest succession have largely concentrated on describing and predicting long-term phytosociological changes in undisturbed systems. Economic factors not only affect the total land area allocated to forest cover, but through the impact of management activities, profoundly influence the ecological process of stand development.

The objectives of this paper are to: (a) present an extant model that projects future areal cover by major forest types, and describe its linkage with other analytical systems for large-scale assessments of natural resource supply trends; and (b) suggest improvements for regional modeling of forest type transitions.

REVIEW OF FORESTLAND BASE RESEARCH

Most models of forest development and succession assume a relatively stable, long-term community (Waggoner and Stephens, 1970; Shugart et al., 1973; Horn, 1974, 1976). Succession is viewed as a dynamic, steady-state adjustment to a given stable environment, while disturbances are conceptualized as exogenous changes setting back succession. Shugart et al. (1973) used ordinary linear differential equations that reflected stand dynamics and silvical characteristics in order to simulate the amounts of forested land in different successional stages in the absence of natural and human-caused disturbances. Waggoner and Stephens (1970) developed a comparable model using a Markov chain, with stationary transition probabilities for forest type shifts. In contrast, Johnson and Sharpe (1976) used nonstationary transition probabilities in a differential equation model to examine a number of land use scenarios. They simulated management effects on forest type shifts in the northern Georgia Piedmont using rates of growth, mortality, harvesting, and land use changes based on average conditions for the 1961–1972 period. Brooks (1985) incorporated a conditional transition probability matrix in a timber inventory projection model of the U.S. South to reflect the outcome of both management practices and natural succession tendencies. His model included a probability distribution for the different possible destinations (future forest types) for each unit of area harvested in each forest cover type.

Forest area data useful for regional level analyses have been collected over the years by several organizations, which have employed different sampling techniques and definitions in some cases. USDA Forest Service Forest Inventory and Analysis (FIA) surveys (e.g., Knight, 1975) provide a time series of area data for forest types on a sub-state basis. Forestland area for all ownerships for a particular state are estimated approximately every 10 years, but the timing of survey cycles among states differs. Other data sources that may be useful for augmenting the FIA forest acreage data include series compiled by the Census of Agriculture and the Soil Conservation Service. The SCS surveys and Census of Agriculture surveys to date have not reported forestland area by forest type, and differ notably in methods and definitions, both among themselves and with surveys of other agencies.

Forest type transitions have received limited attention in large-scale

natural resource supply appraisals such as the 1980 RPA Assessment (USDA Forest Service, 1982). Analytical approaches that have potential application in regional resource supply appraisals include Brooks (1985) and a similar, but more detailed, forest type transition model to be discussed next.

DEVELOPMENT OF THE TYPE TRANSITION MODEL

Alig (1984) developed the Southeast Area Model (SAM), which uses two-stage modeling to project area changes for forest ownerships and cover types. In the first stage, econometrically estimated equations are used to project forest area by the three major private ownerships: farm forest, forest industry, and miscellaneous private forest. In the second stage a forest type transition module projects the distribution of five major types of forest cover – planted southern pine, natural southern pine, oak-pine, upland hardwoods, and lowland hardwoods – on those ownerships.

The simulation process used in the SAM system to project forest type area requires three sets of input data, segregated by owner and physiographic region: (a) original state or distribution of forest types, (b) probability of application of the three management classes, and (c) conditional transition probabilities for a forest type's destination in response to receiving one of the three types of management. The conditional forest type transition probabilities are multiplied by the management probabilities and the initial area in a particular forest type on an ownership (area adjustments by forest type for diversions from and reversions to the timberland base are estimated based on recent survey data). The resultant area estimates are summed by owner, forest type, and physiographic region. The equation form is:

$$A_{i,j,t+1} = \sum_{j=1}^5 \sum_{k=1}^3 P(D_{k(i,j,t)}) P(FT_{i,j,t+1}/D_{k(i,j,t)}) A_{i,j,t}$$

where $A_{i,j,t}$ is the forest area in private ownership i and forest type j in decade t ($i = 1, 2, 3$; $j = 1, \dots, 5$; $t = 1, \dots, 7$); $P(D_{k(i,j,t)})$ the probability of a primary disturbance of type k on ownership i and forest type j in decade t ($k = 1, 2, 3$); and $P(FT_{i,j,t+1}/D_{k(i,j,t)})$ the probability of a unit area of timberland on ownership j in decade $t + 1$ being in forest type j in response to a primary disturbance of type k on that unit area in decade t .

Three classes of treatment or management practices applied to the forestland base are considered in the type transition modeling: no treatment, harvest, and other miscellaneous disturbances. The probabilities of type transition in response to each type of land management are aggregate measures of all influences acting on forest development, including human disturbances and natural succession forces.

TABLE 1

Percentage of forestland on forest industry ownerships in Florida, Georgia, and South Carolina changing from one forest type to another as the result of different primary disturbances between two survey remeasurements

Changes from forest type (source)	Primary disturbance/management	Probability of disturbance/management	Changes to forest type (destination)				
			Natural southern pine	Planted southern pine	Oak-pine	Upland hard-wood	Lowland hard-wood
Natural southern pine	None	33.7	92.9	0.7	4.8	0.0	1.6
	Harvest	24.2	16.4	61.2	7.7	9.0	5.7
	Miscellaneous	42.1	72.8	16.6	6.0	3.0	1.6
Planted southern pine	None	29.2	1.8	94.6	2.1	0.8	0.7
	Harvest	16.9	13.7	57.7	9.5	16.9	2.2
	Miscellaneous	53.9	1.4	95.8	2.0	0.8	0.0
Oak-pine	None	47.7	21.6	6.7	46.1	12.0	13.6
	Harvest	17.7	5.6	25.5	17.4	34.2	17.3
	Miscellaneous	34.6	31.3	32.1	14.5	13.0	9.1
Hardwood	None	61.8	2.6	0.1	6.1	21.0	70.1
	Harvest	10.1	1.1	25.1	4.4	29.0	40.4
	Miscellaneous	28.1	4.7	25.1	7.4	19.2	43.6

Table 1 shows an example set of forest type transition data for forest industry timberland in the Southeast. The conditional transition probabilities are derived from historical data based on forest survey remeasurements made approximately a decade apart.

The use of dynamic transition probabilities (i.e., a unique transition probability matrix for each time period) was not possible because data for developing appropriate adjustment mechanisms were not available. The impact on forest type transitions of changes in management practices, such as increased timber investment levels or acceleration of private harvesting, can be simulated in sensitivity analyses by modifying the probability of management or the transition probabilities associated with certain management practices (or both). Currently, incorporation of more detailed information on timber management practices is precluded by lack of data.

In a practical sense, definitive validation of the SAM forest type transition model is difficult because long-range outcome data for comparisons purposes are not available. Additionally, no independent set of projections of forest type area exists for comparison purposes. SAM projections depend partially on the values of variables or inputs exogenous to the model (e.g., mix of timberland management), and therefore any evaluation is a test of both model structure and input data (Brooks, 1985). SAM results are consistent with published assessments of the likely development of southern

forests (e.g., Boyce and Knight, 1979, 1980). Evaluation of the structure of SAM type transition modeling has also been facilitated by testing in an ongoing southern timber supply study, including sensitivity analyses involving changes in major inputs.

MODEL USE

Linkage of the model of forest type transitions to other models is an important step in furthering the analytical capability in large-scale assessments of prospective natural resource supplies. For instance, the SAM system supports the Timber Resource Inventory Model (TRIM) (Tedder et al., 1983). The TRIM system projects long-term changes in the growth and availability of timber resources to the year 2040. This requires input from SAM pertaining to the number of acres on each ownership projected to be devoted to forestry, including the distribution of forest types, each decade to 2040. Area projections by forest ownership and cover type are also needed as inputs for regional models that project the likely production of other resources (e.g., wildlife) from the forestland base.

Preliminary projections of the distribution of forest types on industry lands prepared for an ongoing study of southern timber resource supplies are presented in Table 2. These projections are predicated on the continued application or mix of the land management practices on each ownership observed in the recent survey remeasurement period. Previous studies used forest area projections derived from expert opinion that were categorized only by ownership class.

Southern pine is the most important commercial forest type, occurring on two-fifths of the timberland in the Southeast. Shifts from pine to hardwood types occur primarily after harvests, especially on nonindustrial lands where pine regeneration efforts are often lacking (Boyce and Knight, 1979, 1980). Additionally, there is a gradual conversion of pine to oak-pine, and then to

TABLE 2

Projections of the percentage distribution of forest types on forest industry timberland in the Southeast

Ownership	1984	2000	2020	2040
<i>Forest industry</i>				
Planted southern pine	35.01	49.49	56.01	59.34
Natural southern pine	20.05	11.64	9.29	8.64
Oak-pine	8.51	6.93	6.65	6.56
Upland hardwood	14.13	16.27	15.20	14.15
Lowland hardwood	22.31	15.67	12.85	11.31

hardwoods, if natural stand development processes are not arrested or reversed. This contributes to the projected reduction in natural southern pine area indicated in Table 2. However, the major factor behind the reduction of natural pine on industrial owned lands is the economic attractiveness of artificial regeneration after harvest of natural pine.

The likely mix of future management applied to the timberland is a major input to SAM and timber inventory projection models used in regional timber supply appraisals. Three different approaches have been used to project the regional mix of timberland management (Alig et al., 1984): (a) extrapolation of management implicit in measured stand growth rates (Larson and Goforth, 1974), (b) positive econometric analysis of timber investment behavior (Brooks, 1985); and (c) economic optimization analysis of timberland treatment opportunities (Tedder et al., 1983). SAM can accommodate management input provided by any of these three approaches.

IMPROVING THE MODELING OF COVER TYPE TRANSITIONS

Gauging the relative importance of ecological and economic factors in influencing forest type transitions (i.e., shifts in area of forest type cover because of either natural forces or human activity) is difficult because of the lack of a quantitative modeling framework based on a broad consideration of principles from both disciplines. Alig's (1984) model is an empirically derived, fixed probability model and highlights the need for a pragmatic blend of economic and ecological theory in the analysis of the Southeast's forest resources. Our current work concentrates on more fully exploring the relation between changes in the form of forest cover distribution through time with: (a) the level of disturbance, and (b) the rate of species turnover on relatively undisturbed areas.

A substantial proportion of the Southeast forest acreage is subject to frequent natural or human disturbance and is clearly not suited to steady-state modeling efforts. Instead, forest development and compositional change can be envisioned as responding to the influence of both disturbance (type and severity) and the predominant silvical characteristics of the tree species involved. The effects of both natural and human disturbances on vegetation occur along continua (Whittaker, 1974; White 1979). Currently, the degree of canopy removal is assumed to sufficiently describe both human and natural disturbance intensity for regional scale models.

It is not possible to predict how a forest community will react to disturbances of varying intensity or to varying lengths of disturbance-free periods without knowledge of the biology of each species involved. Yet too much detail of this sort would prove unworkable and too costly on a regional basis. The five timber types discussed earlier do not provide a suitable level

of resolution for this purpose. As a result, we divided the Southeast forest tree species into four major groups based on combinations of silvical characteristics vital to the vegetation dynamics of the area (Nobel and Slatyer, 1977, 1980; Cattelino et al., 1979). The species in these groups have more or less equivalent roles in the post-disturbance replacement sequences examined. The four groups are:

- (1) DI, Dispersed, intolerant hardwoods (e.g., yellow-poplar, sweetgum);
- (2) CI, Canopy-seeded, intolerant pines (e.g., yellow pines);
- (3) DT, Dispersed, tolerant hardwoods (e.g., maples, tupelo, baldcypress);
- (4) CT, Canopy-seeded, tolerant hardwoods (e.g., oaks and hickories).

In relation to the five forest types discussed earlier, these groupings divide the hardwoods on the basis of silvical characteristics as opposed to site (i.e., bottomland versus upland). However, most bottomland hardwoods fall into the DT group. Additionally, for regional modeling purposes pines are considered the same whether they are planted or naturally seeded.

Our preliminary analysis of vegetation replacement sequences based on vital attributes indicates that recurrent disturbances other than fire and old field land abandonment lead to hardwood dominance. More frequent disturbances favor the DI species type, although the DT species type is always a component, while infrequent disturbances favor the CT species type. Yellow pines are favored only by soil disturbance such as old field abandonment and by relatively frequent fires.

We have expanded the general vital attribute and disturbance analysis outlined above to an analysis of a time series of historical data, including disturbance incidence, on major forest type areas. The results of this analysis will form the basis of a dynamic type transition routine sensitive to both natural and human-origin disturbance processes.

Further elaboration and specification of linkages between economic and ecological forces will enhance our ability to identify biologically unstable system components and predict future behavior of those currently unstable situations critical to the timber supply assessment process (e.g., pine reversion to hardwoods). Ultimately, research may provide an overall model capable of handling this broad problem, including more strongly linking the modeling of forest type transitions to timber inventory projection, harvest, and investment modeling in aggregate timber supply studies (Alig et al., 1984). However, given the state of the art and the cost and time required to embellish data sets, analysts will be forced in the interim to separate the overall problem into smaller, more tractable components.

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